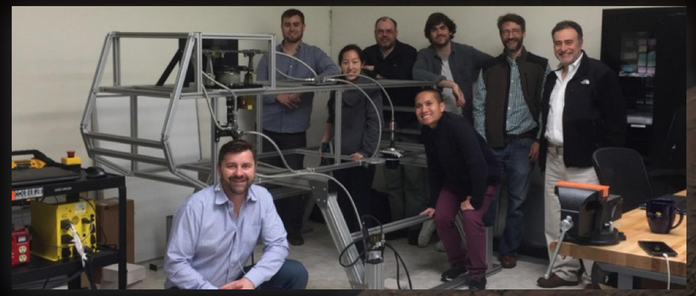
National Aeronautics and
Space Administration

TI&E NASA Advisory Council

Science Mission Directorate Update

Michael Seablom, Chief Technologist, SMD - 1 September 2020

Executive Summary



SMD Technology Highlights are now posted online every 2-3 weeks. Recent articles include "Playing Lacrosse on Titan" (top) and "High Flying Moon Sensor Will Help Improve Earth Observations (bottom).

https://science.nasa.gov/technology

- SMD's technology programs continue to develop capabilities needed for science missions of the future
- We have a significant number of new collaborations with STMD
- We are improving our SBIR strategy
- We are supporting the OCT Strategic Technology Integration Framework
- We are making progress with interagency partnerships
- We are actively engaging entrepreneurs and startups
- We are continuously evaluating our programs and making necessary adjustments

Active SMD Technology Programs

Total FY19 SMD Technology Investments = $509 M

SMD solicitations driven by science priorities from the National Academies

Heliophysics	Earth Science		Planetary Science		Astrophysics	Crosscutting
Heliophysics Flight Opportunities for Research & Technology (HFORT)	Instrument Incubator (IIP)	Sustainable Land Imaging Technology (SLIT)	Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO)	Scientific Exploration Subsurface Access Mechanism for Europa (SESAME)	Strategic Astrophysics Technology (SAT)	Applied Information Systems Research (AISRP)
Heliophysics Technology and Instrument Development (HTIDS)	Advanced Component Technology (ACT)	Decadal Survey Incubation (DSI)	Maturation of Instruments for Solar System Exploration (MATISSE)	Lunar Surface Instrument and Technology Payloads (LSITP)	Astrophysics Research and Analysis (APRA)	
	Adv Info Systems Technology (AIST)	In-Space Validation of Earth Science Technologies (InVEST)	Development of Advanced Lunar Instruments (DALI)	Astrodynamics - Tools (ADYN)	Nancy Grace Roman Technology Fellows (RTF)	
			Concepts for Ocean Worlds Life Detection Technology (CLDTECH)	High Operating Temperature Technology (HOTTECH)		
			Instrument Concepts for Europa Exploration (ICEE)	Planetary Science & Technology Through Analog Research (PSTAR)		

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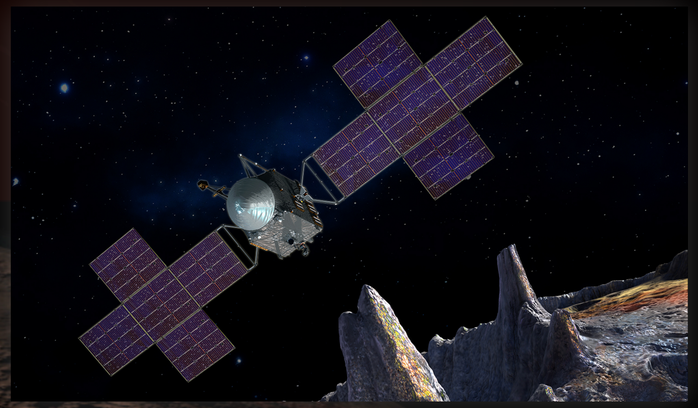
			Concepts for Ocean Worlds Life Detection Technology (CLDTECH)	High Operating Temperature Technology (HOTTECH)	Selections Since November 2019	
			Instrument Concepts for Europa Exploration (ICEE)	Planetary Science & Technology Through Analog Research (PSTAR)		

STMD Collaboration

Technology Demonstrations

Deep Space Optical Communications (DSOC) - technology demonstration on Psyche mission

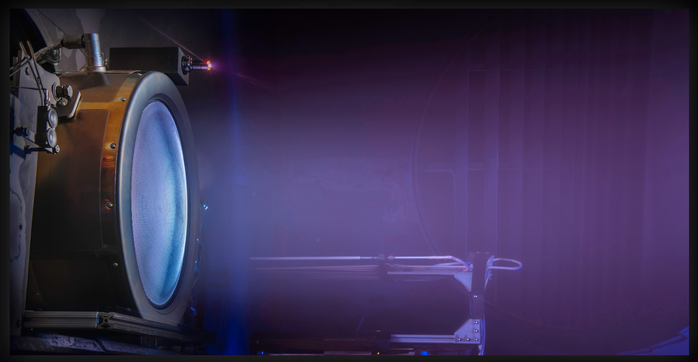


Partial demonstration of NASA Evolutionary Xenon Thruster (NEXT) on DART mission

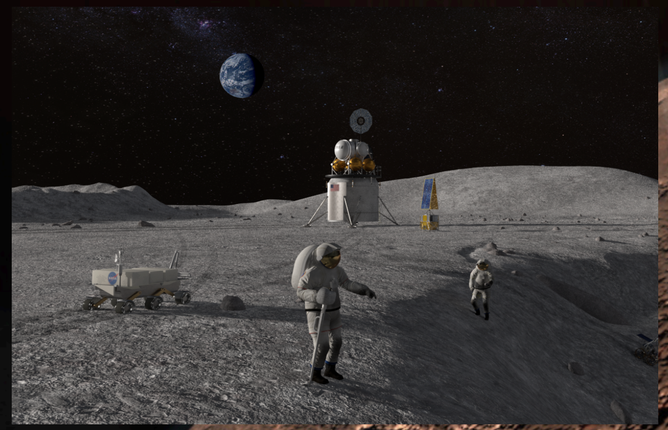
- Discussions underway with STMD for full demonstration

New technologies being offered for Discovery 19

- Deep Space Atomic Clock (DSAC)
- Extreme Environment Solar Panels (EESP) - partial technology demonstration on DART mission
- Heatshield for Extreme Environment Entry Technology (HEEET)
- Long-Lived In-Situ Solar System Explorer (LLISSE)



Artemis Support



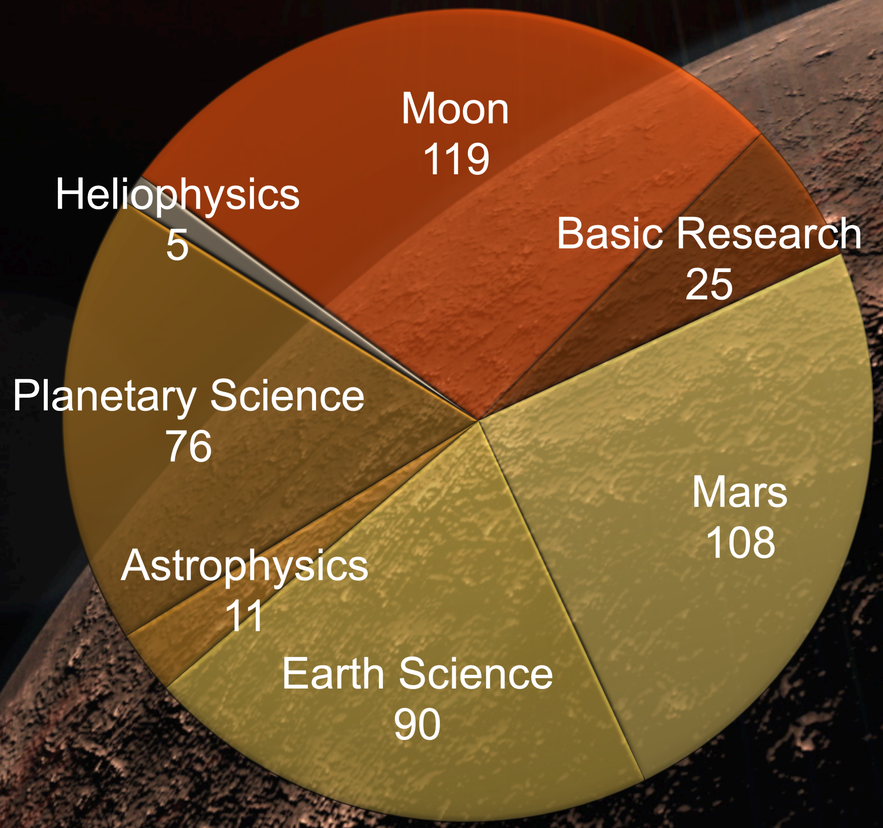
DALI and LSITP programs added to support new lunar instruments

Technology development based upon Artemis Science Plan:

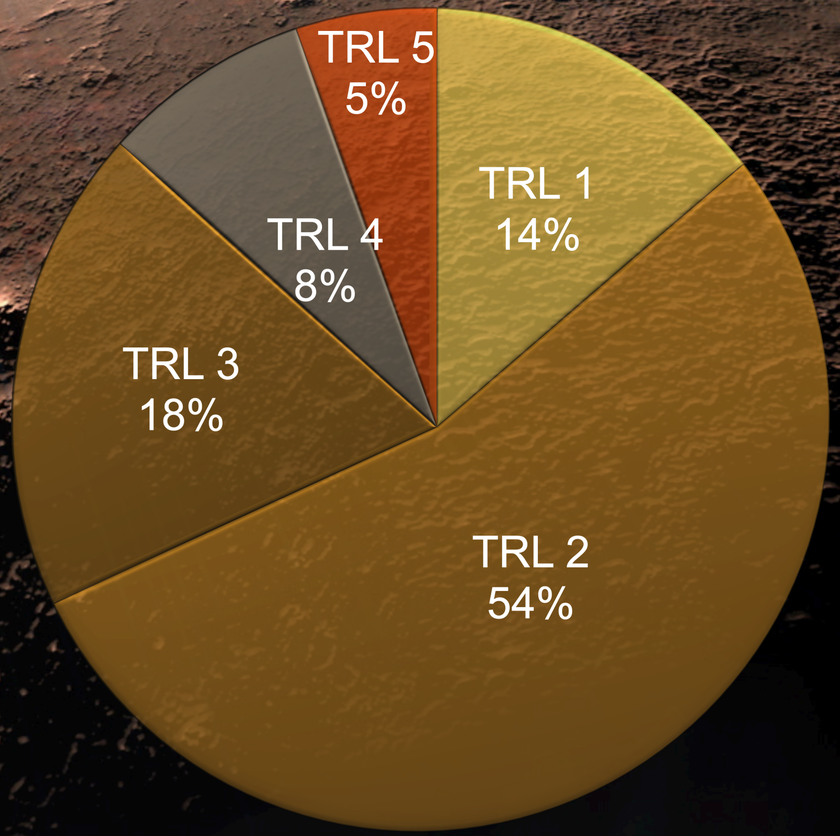
- Study planetary processes
- Understand volatiles cycles
- Discover the history of the Earth -Moon system
- Uncover a record of the ancient sun
- Study the universe from a unique platform
- Enable unique science from the lunar environment

STMD Collaboration

Active Projects - Platform Technologies & Low TRL Science Instruments



Number of Projects per Discipline
(number of projects exceeds 100% of total because of overlap in discipline areas)



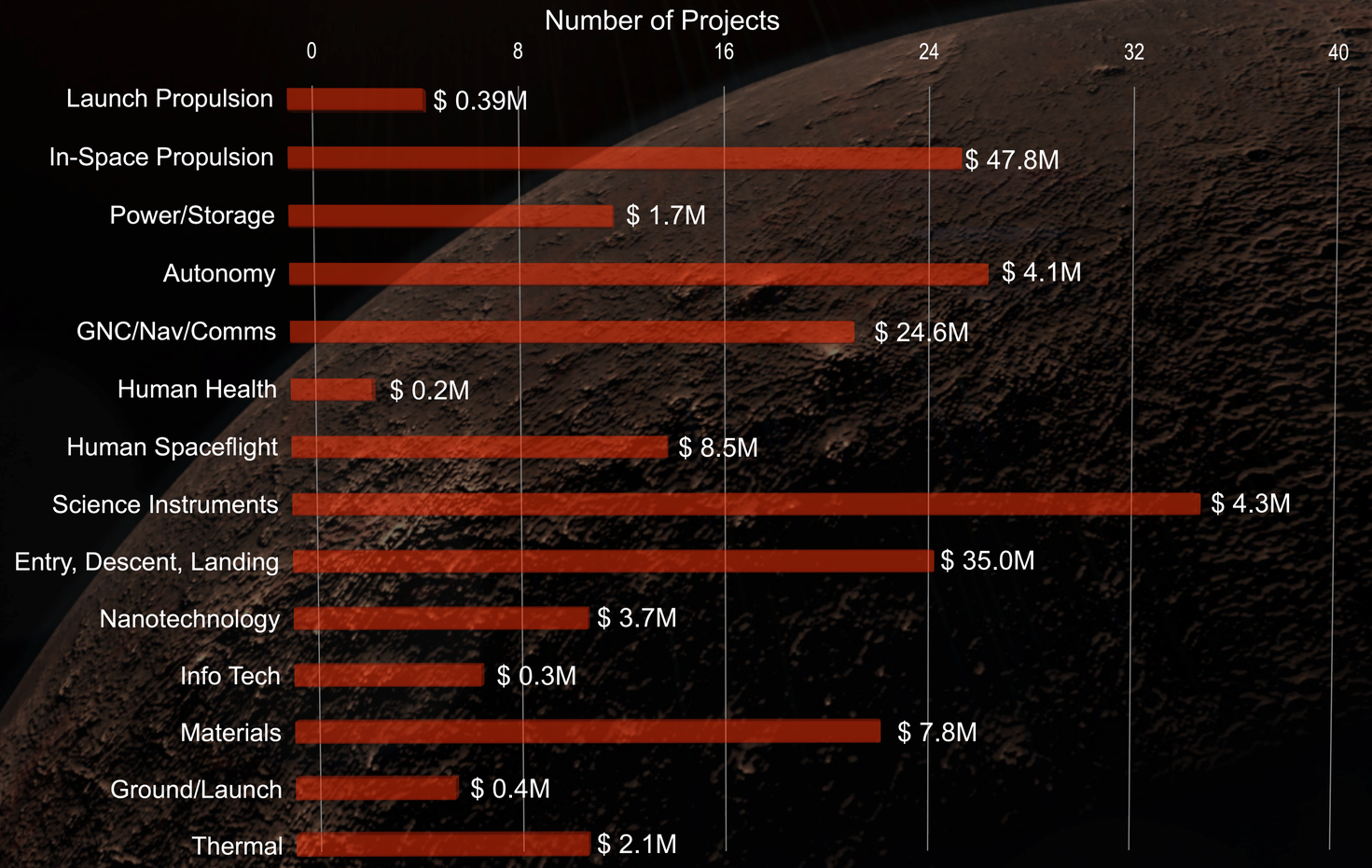
Starting Technology Readiness Levels for Active Projects

Active Projects: 220

Total Investment: $ 140.9 M

STMD Collaboration

Active Projects, Platform Technologies + Low TRL Instruments



All SMD-Relevant Technology Areas

SMD high-priority technology areas funded at about $113M (80% of total investment)

- Electric Propulsion
- Solar Power
- Mobility / Manipulation / System Level Autonomy
- Optical Comms / Revolutionary Comms
- Low-TRL Science Instruments
- Entry / Descent / Landing
- Electronics / Avionics for Extreme Environments
- Computing / Modeling / Simulation

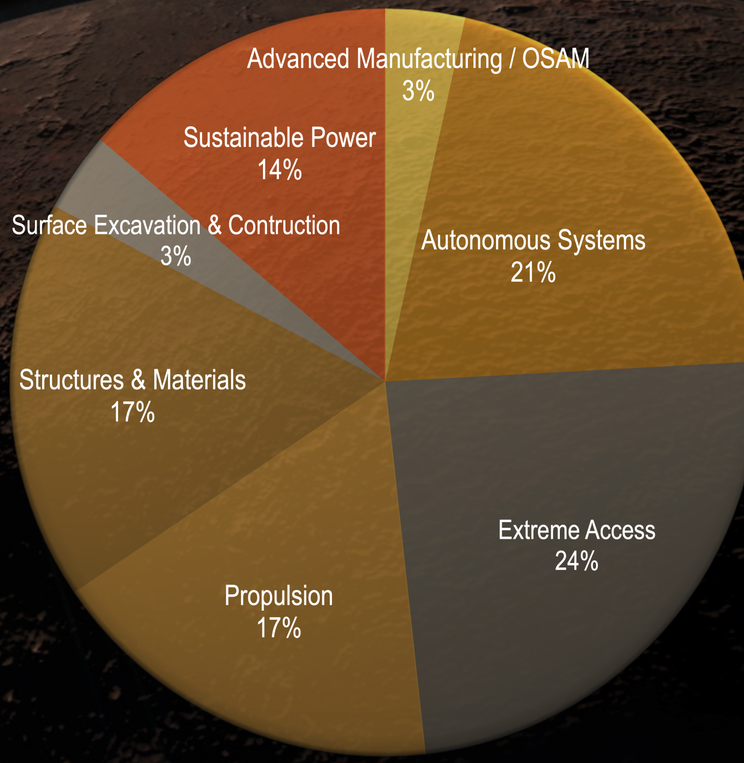
STMD Collaboration

Changes in Game-Changing Development (GCD) Portfolio

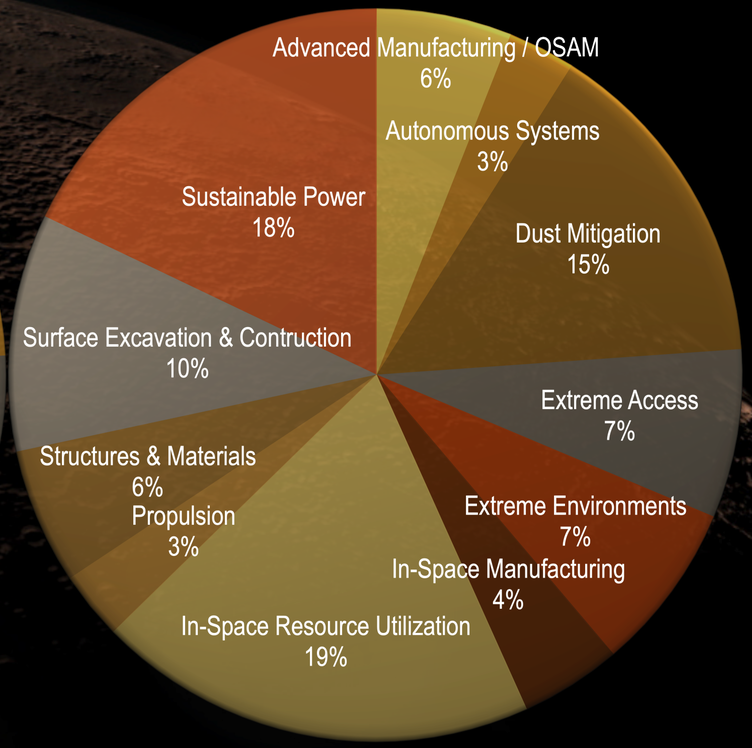
Changes to the GCD portfolio due to lunar initiative may have long-term impacts on SMD

If all mid-TRL STMD solicitations have similar constraints, an approximate 30% loss of high-priority content could occur by 2021, based upon an August 2018 internal SMD study

The Tech Fed is working closely with GCD to maximize cross-cutting investments and to prioritize key science capabilities



GCD - Currently Active



GCD 2021 Proposals

STMD Collaboration

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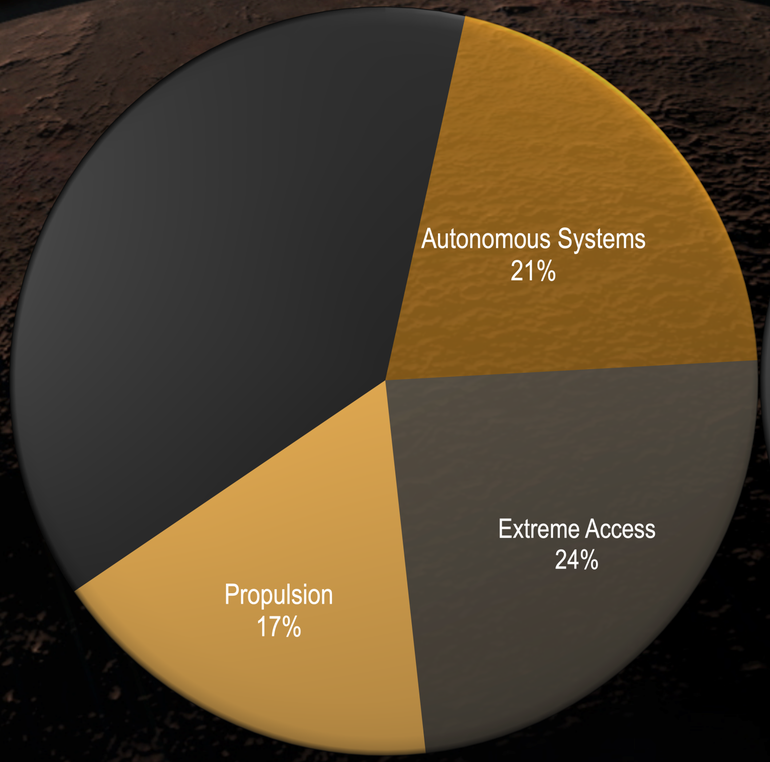
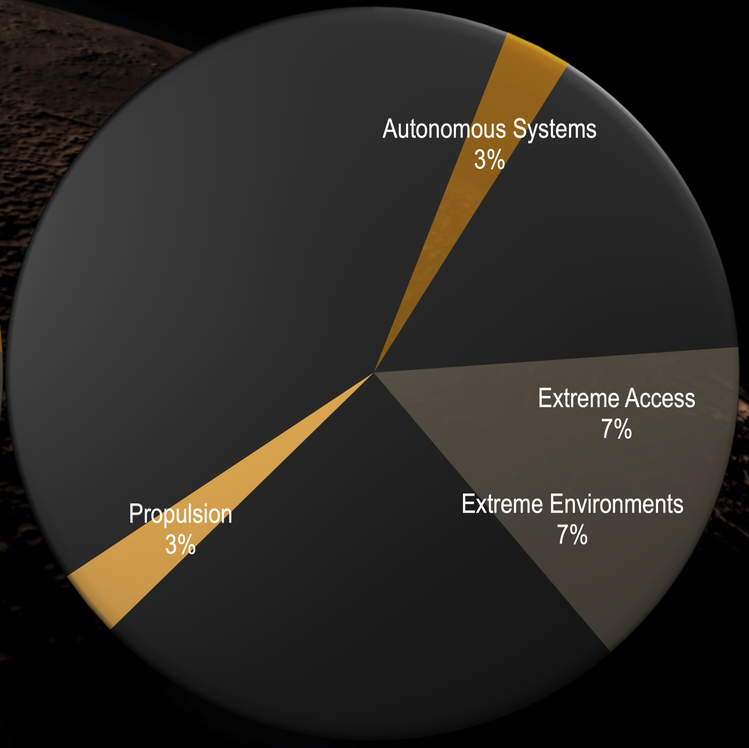


GCD - Currently Active



GCD 2021 Proposals

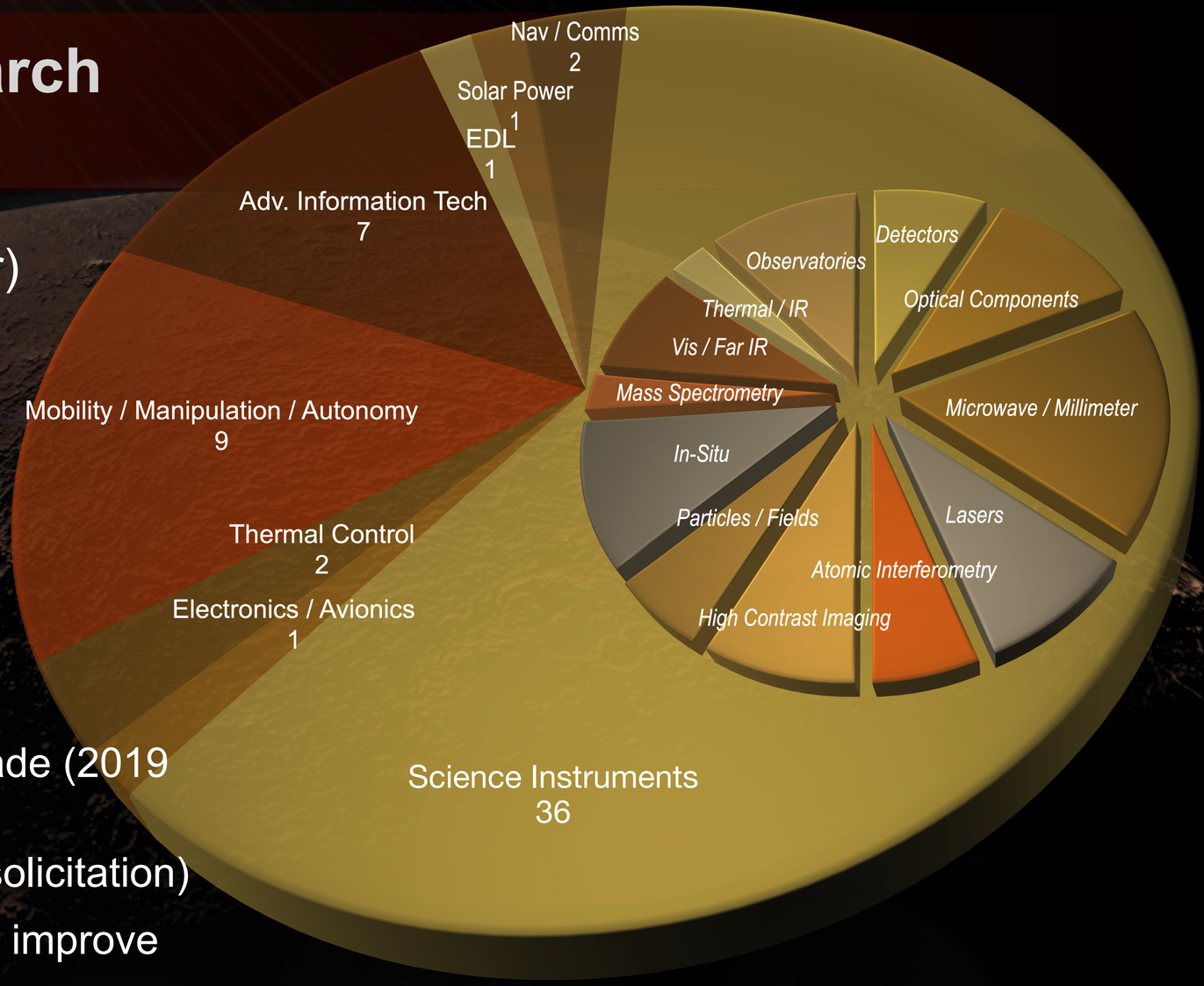
Small Business Innovative Research Program (SBIR)

SBIR Topic Areas for SMD ($93 million / year)

- Sensors, Detectors, and Instruments
- Advanced Telescope Systems
- Spacecraft and Platform Subsystems
- Robotic Exploration Technologies
- Information Technologies

Recent / Current Activities

- 58 Phase II SMD selections (see chart) were made (2019 solicitation)
- 120 Phase I SMD selections were made (2020 solicitation)
- Topic managers met with the Tech Fed in July to improve coordination
- Better linkages between SBIR and SMD technology programs is needed



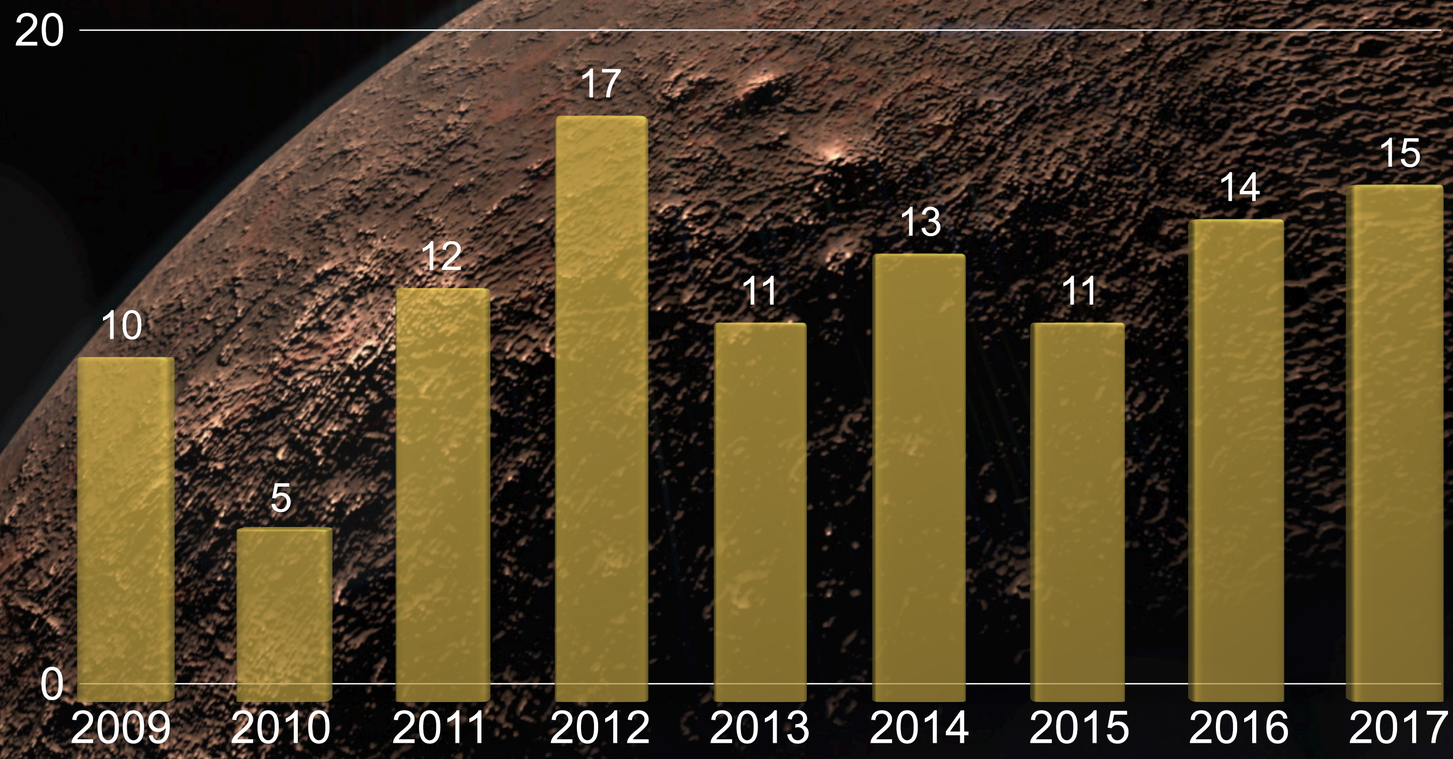
Breakdown of newly-awarded SMD Phase II SBIR Selections by Technology Area

SBIR Program

Success Metrics

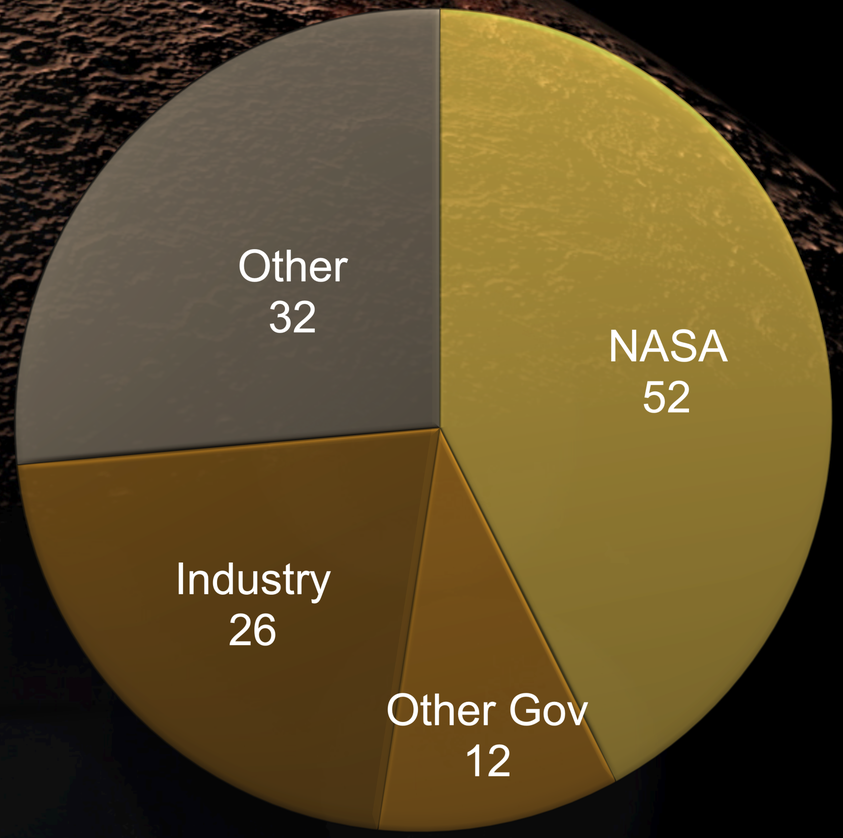
Number of SMD SBIR Project Transitions / Year

Number of Projects, 2009-2017: ~450 Total Transitions: 122 (27%)



Sources of Funding

2009-2017

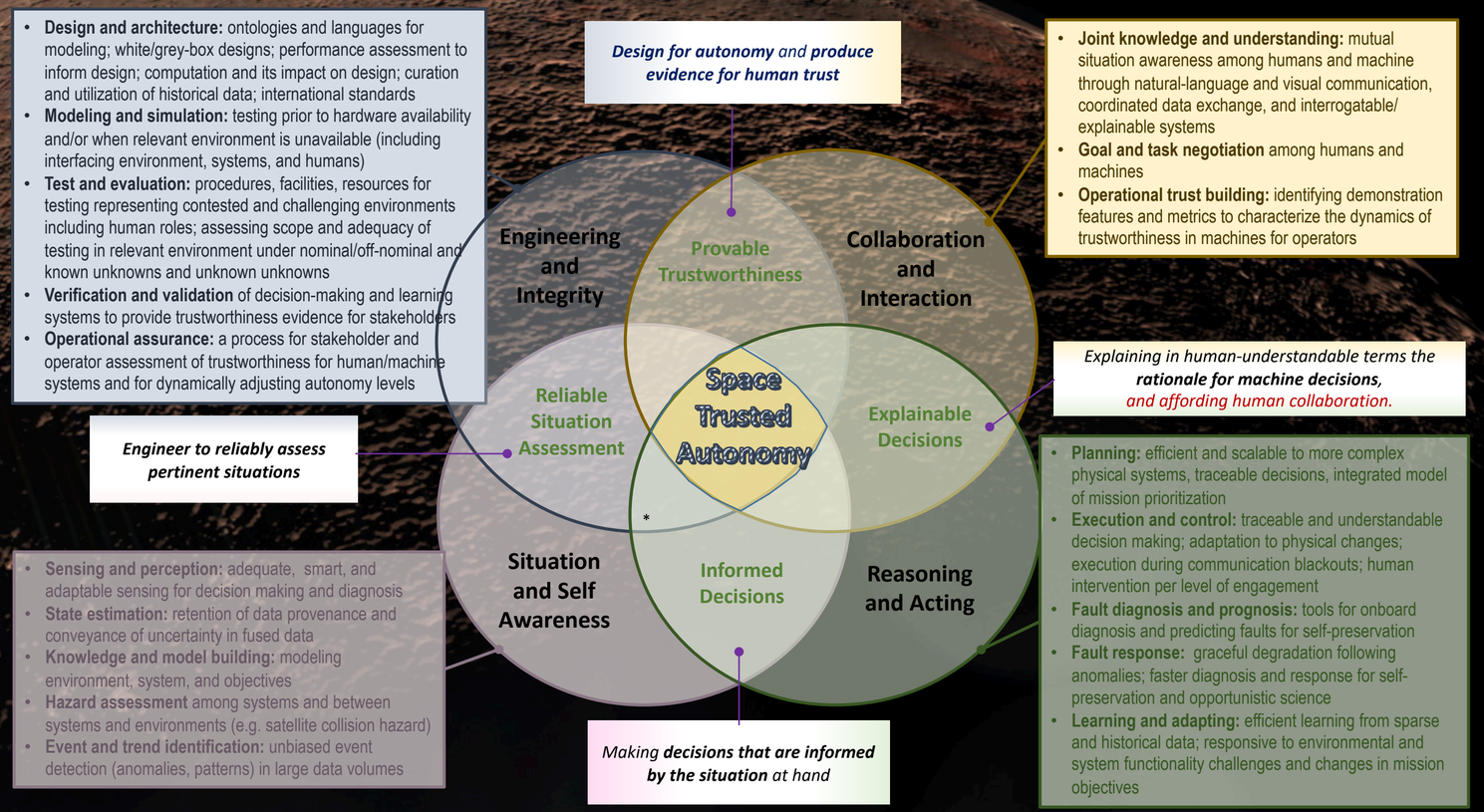


Science & Technology Area: Trusted Autonomy

Office of Chief Technologist (OCT) Initiative

NASA-USAF-NRO initiative - Recommendations for collaboration

1. Standardization of acquiring and dissemination of spacecraft anomaly data
2. Development and deployment of a safe and benign testing environment
3. Training for existing operators to improve technology adoption; development of autonomous capabilities to include humans in the design process



SMD Technology

Watch List

Quantum Sensors	Sensors that make use of quantum entanglement and superposition have the potential for important performance increases in magnetometers, telescopes, radars, gravimeters, and possibly other measuring devices. Status: Full potential of quantum sensors is unknown; an SMD-sponsored study is planned.
Small Satellite Technologies	Miniaturization of science instruments are needed for small spacecraft platforms. STMD investments are necessary to acquire necessary communications, propulsion, thermal management, and power systems. Status: Most SMD instrument programs are contributing; ISSUE: better linkage with STMD is needed for platform technologies is needed.
Intelligent, Autonomous Systems	Science community needs to be aware of advancing capabilities in autonomous systems in order to plan future missions that can deliver better science at lower cost. Status: Outcomes of SMD Autonomy Workshop (2018) has identified new design reference missions and these are now being incorporated into the STMD Space Technology Architecture.
Next-Generation High Performance Computing	Rad-hardened, on-board computing with performance 100X over state-of-the-art is desired for future missions. ISSUE: STMD investment in High Performance Spacecraft Computer (HPSC) has been terminated; new project is now being planned. Neuromorphic computing project is now underway.
Big Data Analytics	Voluminous amounts of data are being generated by active missions and by models, and there are petabytes of data in existence from past missions and from external sources. Computational techniques are needed to fully extract all of the information from these data stores. Status: Advanced Information Systems Technology (AIST) program is addressing some of ESD's needs; Applied Information Systems Research (AISR) program has been resurrected to invest in cross-cutting algorithms for advanced autonomy.

Survey of SMD Applications

Potential Use of Quantum Sensors

Quantum Sensors Workshop,
JPL, September 2019

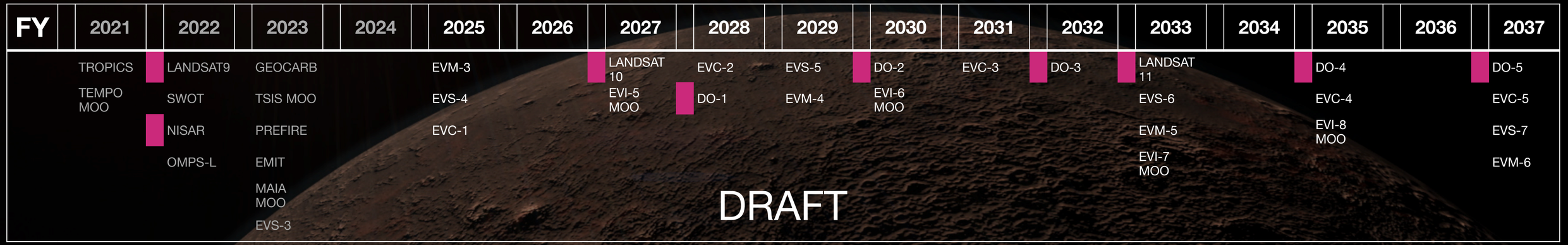
- Theory
- Development
- Mature

- T Theory
- C Commercial
- L Lab

		Atomic Nuclear Spin Gyroscope	Atomic Interferometer	Atomic Electric Field Sensor	Atomic Magnetometer	Atomic Clock	Squeezed Laser Interferometer	Quantum Radiometry Calibrations	Quantum Ghost Imaging	Quantum Radar	Single Photon Sourcing	Quantum Network Sensors	Quantum Synchronization	Collective Entangled Sensors	Single Photon Detection	Quantum Transducer
Planetary Science	Lunar Volatiles															
	Life Detection															
	Seismology															
	Imaging in Low Light															
Astrophysics	Dark Matter Detector															
	Dark Energy Detector															
	Gravitational Wave Detector															
	Far IR Detection															
	CMB Measurements															
Earth Science	Ecosystem Structures															
	Sea Level Rise															
Technology Maturity		L	C	L	C	C	C	L	C	T	T	T	T	L	C	L

Earth Science Technology

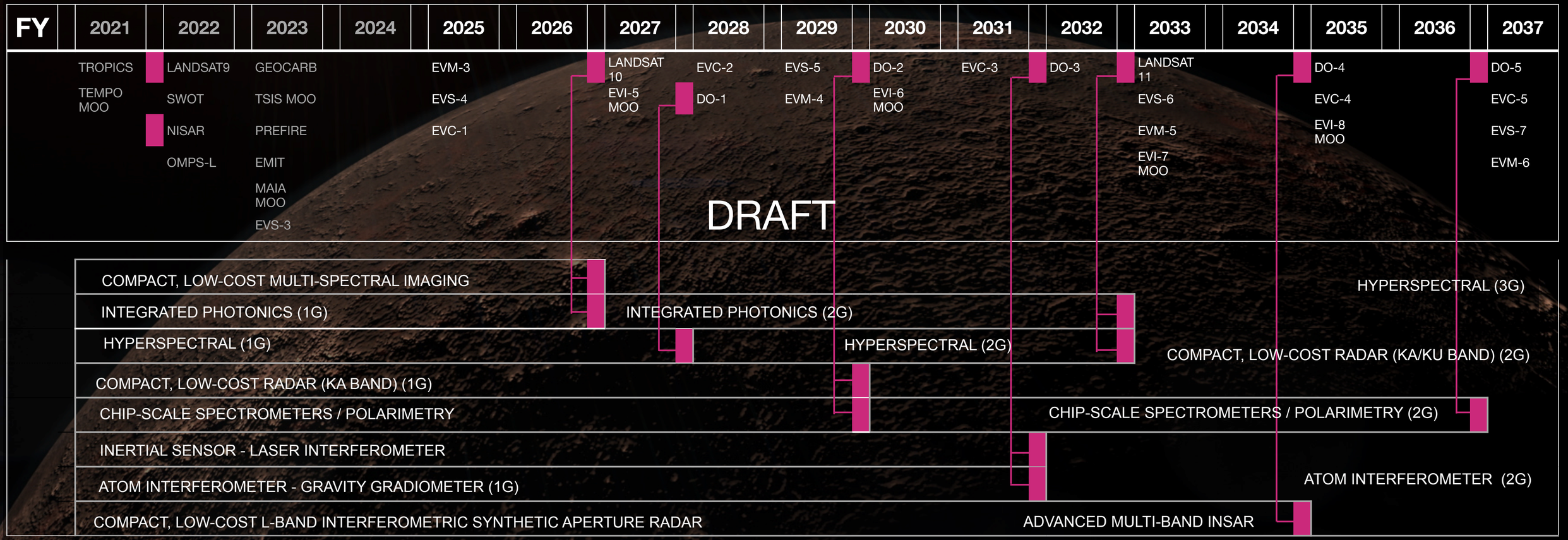
Investments for Designated Observables



Observable	Science/Application	Candidate Measurement Approach
Aerosols	Aerosol properties, aerosol vertical profiles, and cloud properties to understand their effects on climate and air quality	Backscatter lidar and multichannel/multi-angle/polarization imaging radiometer flown together on the same platform
Clouds, Convection, and Precipitation	Coupled cloud-precipitation state and dynamics for monitoring global hydrological cycle and understanding contributing processes including cloud feedback	Radar(s), with multi-frequency passive microwave and sub-mm radiometer
Mass Change	Large-scale Earth dynamics measured by the changing mass distribution within and between the Earth's atmosphere, oceans, ground water, and ice sheets	Spacecraft ranging measurement of gravity anomaly (laser ranging or atomic interferometry)
Surface Biology and Geology	Earth surface geology and biology, ground/water temperature, snow reflectivity, active geologic processes, vegetation traits and algal biomass	Hyperspectral imagery in the visible and shortwave infrared, multi- or hyperspectral imagery in the thermal IR
Surface Deformation and Change	Earth surface dynamics from earthquakes and landslides to ice sheets and permafrost	Interferometric Synthetic Aperture Radar (InSAR) with ionospheric correction

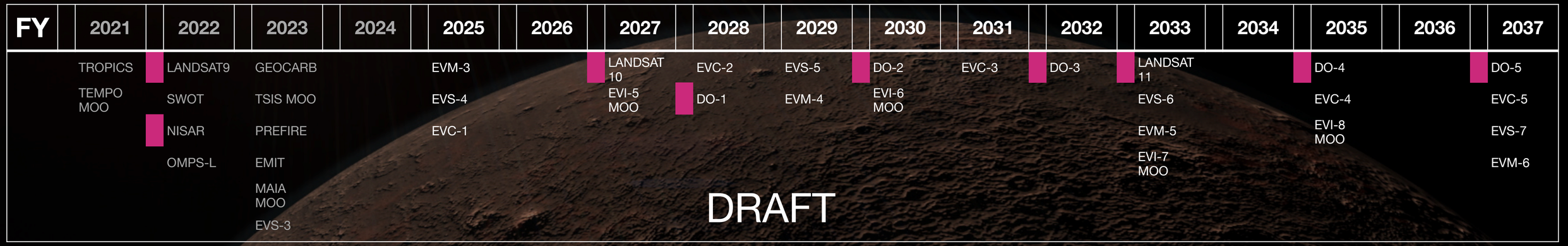
Earth Science Technology

Investments for Designated Observables & Landsat Missions



Earth Science Technology

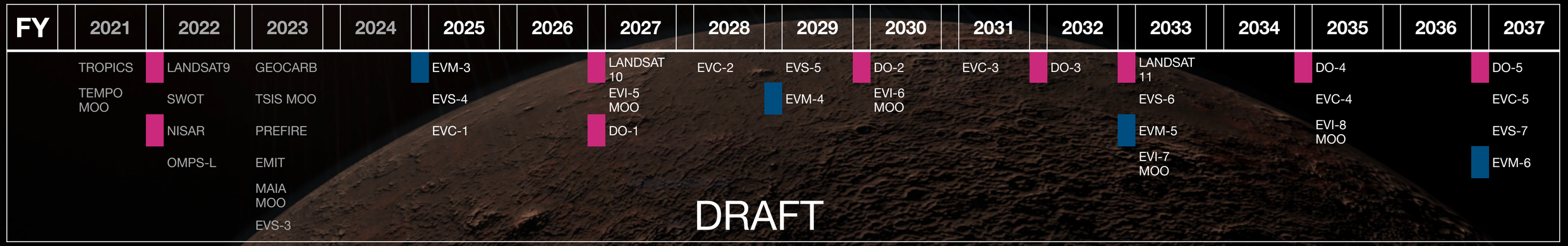
Investments for Earth System Explorer Missions



Earth System Explorer	Science/Application	Candidate Measurement Approach
Greenhouse Gases	CO2 and methane fluxes and trends, global and regional with quantification of point sources and identification of sources and sinks	Multispectral short wave IR and thermal IR sounders; or lidar
Ice Elevation	Global ice characterization including elevation change of land ice to assess sea level contributions and freeboard height of sea ice to assess sea ice/ocean/atmosphere interaction	Lidar
Ocean Surface Winds and Currents	Coincident high-accuracy currents and vector winds to assess air sea momentum exchange and to infer upwelling, upper ocean mixing, and sea-ice drift	Doppler scatterometer
Ozone and Trace Gases	Vertical profiles of ozone and trace gases (including water vapor, CO, NO2, methane, and N2O) globally and with high spatial resolution	UV/Vis/IR microwave limb/nadir sounding and UV/Vis/IR solar/stellar occultation
Snow Depth and Snow Water Equivalent	Snow depth and snow water equivalent including high spatial resolution in mountain areas and landslides to ice sheets and permafrost	Radar (Ka/Ku band) altimeter, or lidar
Terrestrial Ecosystem Structure	3D structure of terrestrial ecosystem including forest canopy and above ground biomass and changes in above ground carbon stock from processes such as deforestation and forest degradation	Lidar
Atmospheric Winds	3D winds in troposphere/PBL for transport of pollutants/carbon/aerosol and water vapor, wind energy, cloud dynamics and convention, and large-scale circulation	Active sensing (lidar, radar, scatterometer); passive imagery to generate motion vectors

Earth Science Technology

Investments for Decadal Survey Incubation Missions



Incubation	Science/Application	Candidate Measurement Approach
Planetary Boundary Layer	Diurnal 3D PBL thermodynamic properties and 2D PBL structure to understand the impact of PBL processes on weather and AQ through high vertical and temporal profiling of PBL temperature, moisture and heights	Microwave, hyperspectral IR sounder(s) (e.g., in geo or small sat constellation), GPS radio occultation for diurnal PBL temperature and humidity and heights; water vapor profiling DIAL lidar; and lidar for PBL height
Surface Topography and Vegetation	Coincident high-accuracy currents and vector winds to assess air sea momentum exchange and to infer upwelling, upper ocean mixing, and sea-ice drift	Doppler scatterometer

The “Entrepreneur’s Challenge”

New Initiative

Goal: Provide early-stage companies with an “on ramp” to SMD technology programs

Provide a $100K prize for those with novel ideas in three targeted areas:

- Quantum sensing to support high precision measurements of gravity, magnetic fields, dark energy, and other measurements to support NASA science
- Transfer Learning and Artificial Intelligence to support on-board autonomy for enabling new science, and to support fault detection and recovery for future science missions
- Novel, high-resolution spectrometers that are low size, weight, and power for Earth observation and for life detection on planetary surfaces

Entrepreneur's Challenge - Schedule

Round 1

Solicitation Released: Broad call for companies & VCs in the topic areas

May 18

Registration Opens; first draft of judges, speakers, program managers, and invitees identified

Jun 6

5-page White Papers Due

June 26

Evaluation Period

White Paper Evaluations Complete; Invitations Distributed

July 13

Round 2

"Entrepreneur's Challenge" live pitch event (virtual) to program managers, VCs;10-15 winners announced; $20k prizes

July 29

Teams refine concepts & develop proposals for Round 2

August

SMD & SBIR Mentoring

September

SBIR Innovation Opportunity Conference

Round 2 proposals evaluated & selected by program managers; $80K prize

October

November

Round 3

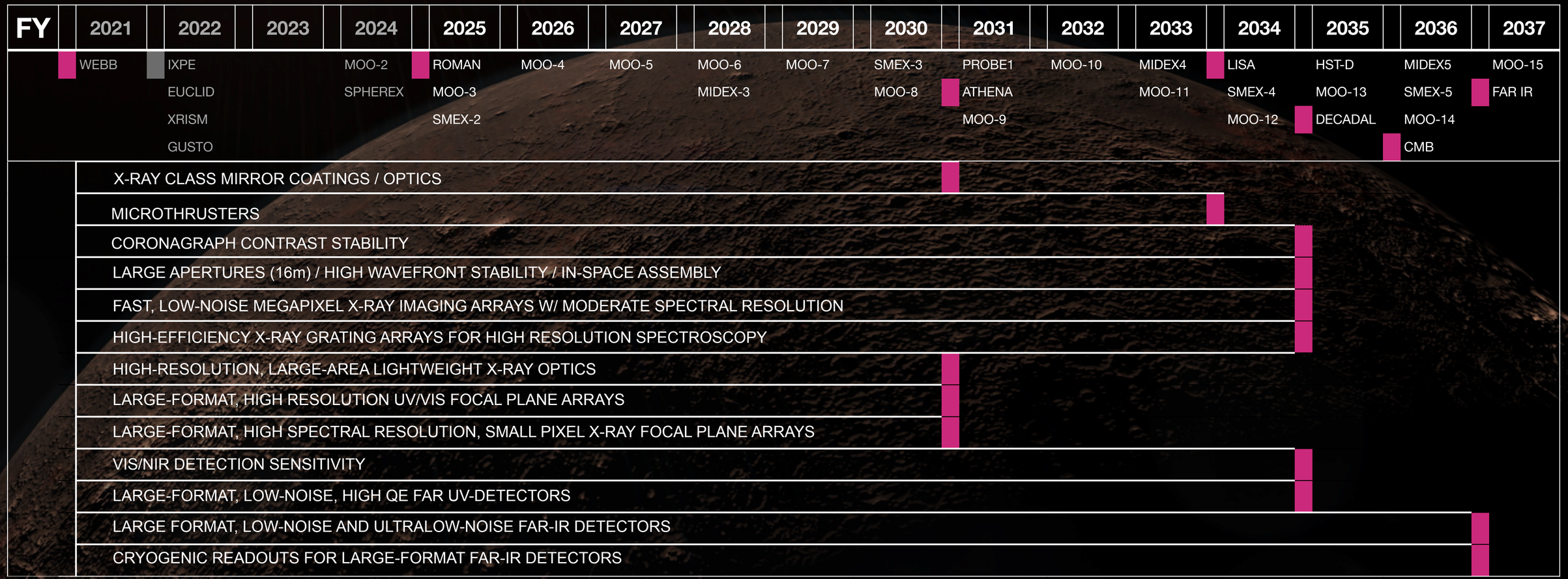
Mentors identify appropriate solicitations (including SBIR) that match concepts and suggest NASA centers with whom they could partner

Early 2021

HTIDS	SLIT	DALI	ADYN
HFORT	DSI	CLDTCH	APRA
IIP	INVEST	HOTTECH	SAT
ACT	PICASSO	SESAME	RTF
AIST	MATISSE	LSITP	ICEE

Backups

Astrophysics Technology



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Astrophysics Technology

TIER 2 Technology Priorities

- Advanced Millimeter-Wave Focal-Plane Arrays for CMB Polarimetry
- Detection Stability in Mid-IR
- Heterodyne FIR Detector Arrays and Related Technologies
- High-Efficiency Object Selection Technology for UV Multi-Object Spectrometers
- High-Performance Spectral Dispersion Component/Device
- High-Reflectivity Broadband FUV-to-NIR Mirror Coatings
- High-Throughput Bandpass Selection for UV/Vis
- Large-Format Object Selection Tech for Multi-Object Spectrometers - HABEX
- Starshade Deployment and Shape Stability
- Starshade Starlight Suppression and Model Validation
- Stellar Reflex Motion Sensitivity – Astrometry
- Stellar Reflex Motion Sensitivity – Extreme Precision Radial Velocity

TIER 3 Technology Priorities

- Advanced Cryocoolers
- High-Performance, Sub-Kelvin Coolers
- Large Cryogenic Optics for the Mid-IR to Far-IR
- Long-Wavelength-Blocking Filters for X-Ray Micro-Calorimeters
- Low-Noise, High-QE UV Detectors
- Low-Stress, Highly Stable X-Ray Reflective Coatings
- Photon-Counting, Large-Format UV Detectors
- Polarization-Preserving Millimeter-Wave Optical Elements
- UV Coatings
- UV Detection Sensitivity
- UV/Vis/NIR Tunable Narrow-Band Imaging Capability
- Warm Readout Electronics for Large-Format Far-IR Detectors

Heliophysics Technology

Investments for Competed Missions

FY	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
			PUNCH	MIDEX MOO	IMAP	MIDEX-1	GDC	STP-6		MIDEX-2	EXP MOO-8	STP-7	LWS MOO-11	LWS-8	EXP MOO-13	STP-8	
			TRACERS		STP SCI MOO			SMEX		LWS MOO-8	STP MOO-10	SMEX-3		MIDEX-3		SMEX-4	
			SUNRISE		STP TECH MOO			EXP MOO-7						EXP MOO-12			

- LOW BACKGRND ENERGETIC NEUTRAL ATOM INST
- LYMAN-ALPHA DOPPLER IMAGER
- DUST DETECTOR
- MINIATURIZED MAGNETOMETERS, ELECTRON SPECTROMETERS
- ELECTRON SPECTROMETERS
- ION VELOCITY METERS
- HIGH RESOLUTION ABUNDANCE ANALYSIS
- MEGA CONSTELLATIONS (comms, clocks)
- OPTICAL COMMUNICATION
- ELECTRIC SAIL PROPULSION
- SODIUM LIDAR
- SOLAR SAILS
- SMALL SATELLITE PLATFORM TECHNOLOGIES (POWER, COMM, PROPULSION, ETC)
- SPACE WEATHER NUMERICAL MODELING / MACHINE LEARNING / ARTIFICIAL INTELLIGENCE

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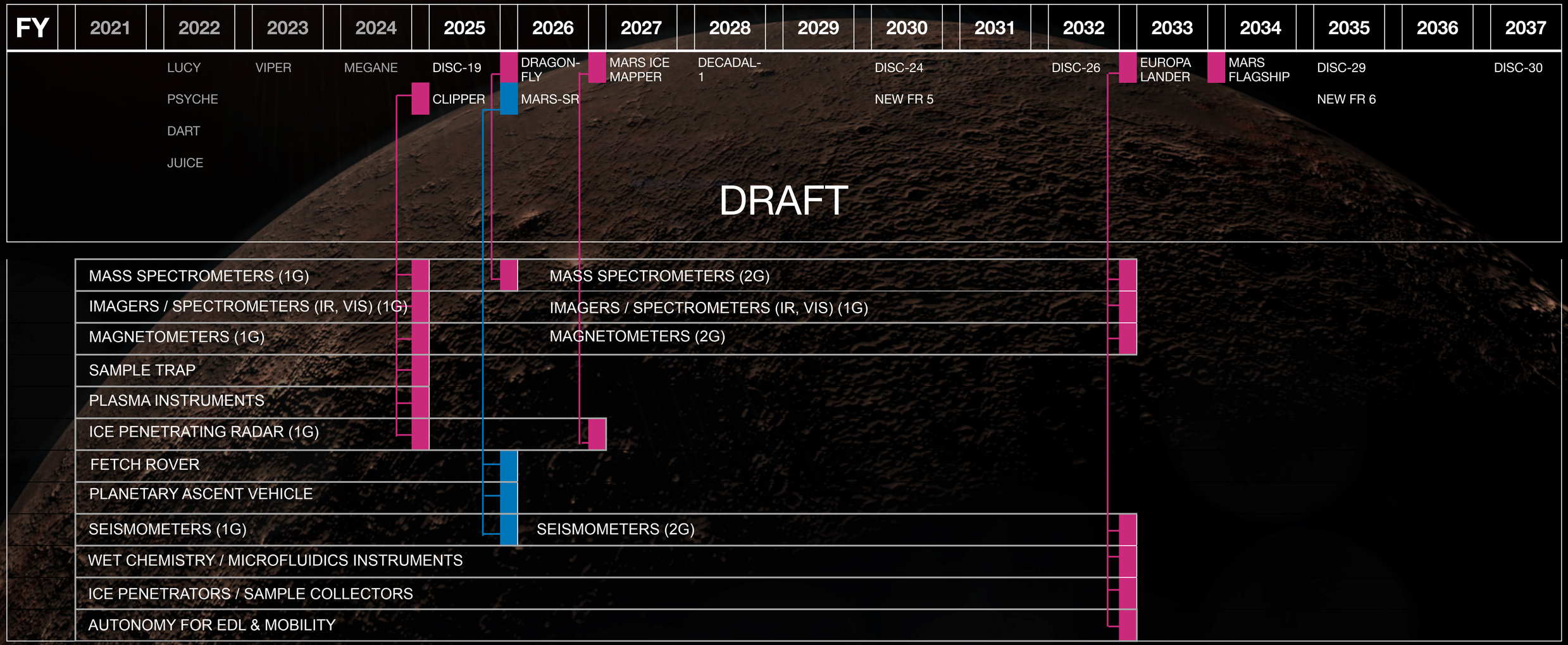
Planetary Science Technology

Investments for Strategic Missions



Planetary Science Technology

Investments for Competed Missions

Extreme temperature compatible, low power, rad-hard electronics

Extreme temperature compatible actuators/mechanisms

Planetary protection techniques / component and material compatibility

Sub-surface (>0.2m) ice acquisition and handling

Ice sample return

Pinpoint landing systems

High-end computing for surface rovers and spacecraft

RPS surface power

RPS orbital power

Advanced autonomy (system, instrument)

Toward a Strategy for Quantum Sensors

- Which applications of quantum sensors will address science needs per Decadal Surveys for Astrophysics, Earth Science, Heliophysics, Planetary Science?
- How do we build our workforce?
- How should our Centers and facilities be aligned?
- What partnerships with other Government agencies, academia, and industry need to be established?
- What changes do we need to make to our technology programs to build capabilities?

The “Entrepreneur’s Challenge”

Round 2 Selections

Next Steps

- Mentors have been assigned to each company to assist in linking their capabilities to a NASA problem
- The companies will make a second pitch at the Innovation Opportunity Conference for an $80K prize
- NASA’s SBIR program will offer support to the companies in preparing a Phase I proposal
- Mentors will also provide advice for preparing ROSES proposals

Company	Mentor	Topic Area
Energi	Marge Cole	Machine Learning
Qunnect	Dan Cremons	Machine Learning
Cognitive Space	Sreeja Nag	Machine Learning
Eric Eaton	Michael Little	Machine Learning
MOBILion	Andrej Grubisej	Mass Spectrometers
Trace Matters	William Brinckerhoff	Mass Spectrometers
Guardion	Paul Mahaffy	Mass Spectrometers
Cold Quanta	Parminder Ghuman, Marco Quadrelli, Sheng-wey Chiow	Quantum Sensors
Tarsier	Nan Yu	Quantum Sensors
Aperio	Frank Maiwald	Quantum Sensors

New on the Horizon

Planning is underway for the first ARMD / SMD Technology Workshop

The Tech Fed is discussing an “Innovation Breakthrough Program”

- Our existing programs solicit for ideas at mostly mid-TRLs, and they provide relatively small amounts of funding over 1-3 years
- Innovation is nearly all incremental — there have been few “breakthroughs”
- Discussions are underway for a program that pushes the limits of basic research with sufficient, dedicated resources to build new capabilities